FENIX 2.0

TEAM CHILE / USM

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U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON 2020

Market Potential Jury Narrative

Team Chile is participating in the Solar Decathlon 2020 [1] with a solar-powered representative dwelling called "Casa FENIX 2.0", a single-family unit of mixed-use multifamily and multi income development that is innovative, cost-effective, and energy-efficient. Casa FENIX 2.0 starts from the "Metamorphosis" concept, which sees housing as a process that adjusts to the family life cycle and changes of family profiles, fostering high flexibility by continuous architectural transformability from an early stage of design. Originally, Team Chile's approach was to target urban infill issues with solar housing development. However, faithful to its resilient philosophy, our current prototype has adapted to respond to a post-disaster reconstruction after a devastating fire last December in Valparaíso, Chile. This version FENIX 2.0 will be the Uribe-Troncoso family home as part of the reconstruction program of the Ministry of Housing and Planning, MINVU, through the subsidy given by Housing and Planning Regional Authority, SERVIU of Valparaíso. The present project will continue later to build more FENIX 2.0 as a triplex and small residential clusters for the reconstruction of 245 lost homes.

Statistics

In Chile, Life Expectancy at Birth has tripled. In 1900 it was estimated at 23.6 years for women and 23.5 years for men and for the period 2015-2020 it is 82.1 for women and 77.3 for men. This means that in the last 100 years the Life Expectancy at Birth has tripled (INE, 2020).

In addition, there is the recurring theme of forest fires that annually affect homes or bushes. The area affected in each period of forest fires averages 52,000 hectares burned, but with extreme values that have ranged from 10,000 to 101,000 hectares (CONAF, 2020)

Another recurring theme is the issue of earthquakes in Chile, which is where one of the highest levels of seismic activity in the world is concentrated, with an average of 200 earthquakes between perceptible and imperceptible being recorded daily (CSN, 2015).

Market Scenario

Taking the previous experience of participatory design of Casa FENIX HC, Team Chile focused first the proposal on a community affected by the problem of gentrification, and as the project evolved, the occurrence of a new urban fire in Valparaiso arose, affecting 39 low-income families. Also, in a country marked by social and natural disasters the resilience factor becomes an opportunity for reconstruction and rebuilding after any of these catastrophic and recurrent events that affects the most vulnerable sector of our society. The reconstruction of houses after a disaster that has affected any poor sector of our society is normally assumed by the government, therefore the housing authority demands creative and fast solutions to house the people that have become homeless. Our local housing authority, SERVIU, knew well about our past and current participation in SD and asked Team Chile to use the new and revised version of Casa FENIX to build the first reconstruction home after this last event. In consequence, Team Chile agreed and took this new challenge of demonstrating that solar and energy efficiency features must be part of governmental social housing, by providing an affordable, creative and innovative solar home, to be financed with the available housing subsidy for reconstruction with the further agreement of converting this project in a timber social housing typology, and build triplex and duplex in the near future. The latest actions and decision of the allocation of SD 2020 Casa FENIX 2.0 were taken in early 2020 when the Covid19 pandemic period was starting in Chile. For it, Team Chile and SERVIU analyzed the 39 family profiles and property locations, met with some of victims and decided to grant Uribe-Troncoso family with Casa FENIX 2.0, the first reconstruction subsidy after the aforementioned fire.

Clean and Affordable Energy

In our design proposal, sustainability and resilience are the highest expected values and contributions. Thus, our design proposal aims to support an energy-conscious, adaptability to growth of Chilean families. The house is also designed to withstand wildfire events and to resist high-energy earthquakes. Furthermore, every device and appliance incorporated in the house allows energy cost-savings such as in heating and ventilation, gas and electricity, and in water reservoirs to mitigate possible fires.

Our photovoltaic system captures energy throughout the day, which is used to heat the water from showers and for cooking. This approach saves money by avoiding the use of grid power and gas.
Rainwater and Greywater systems collect water from the kitchen, showers, washing machine, and sinks. All the collected water is treated by means of a filter system and is stored in reservoirs to be used in case of fires or to irrigate trees and plants in the house.
The natural insulation system reduces the carbon footprint and because it allows the house to have a better thermal behavior when facing the constant temperature variations on the hills of Valparaíso.
The natural wood light filter system allows a precise light balance at the brightest hours of each season of the year, especially on the facades with the greatest sun exposure.

Technological Innovations Incorporated into the house

Households that change their composition, needs and capabilities over time; homes that get sick, crash, expand, reduce; inhabitants that regularly or unexpectedly leave their homes to move permanently somewhere while others are just settling... All of these are just common-life situations.

Still, they are not fully addressed by the static nature of current building design and construction. In order to tackle these issues, a resilient philosophy together with the right technological approach is the strategies for success. In this section we present the technological innovations we are using in our project.

Resilience First

One important consideration for the Fenix 2.0 project is the resilience factor regarding family life-cycle changes, seismic and other natural disasters, and climate change. In Chile, the most seismic country in the world, all buildings must comply with strict seismic standards to respond to the recurrent seismic activities with great energy release. Also, in recent years we have had several devastating wild and urban fires that have destroyed thousands of homes.

Even further, the whole world is today facing a climate crisis, which affects the way we design, build, and operate buildings. Subsequently, we must acknowledge our proposal from the spirit of "resilience". According to UNISDR, resilience is "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions".

Sustainable Flexibility

In order to be environmentally sustainable, any building must ensure the care for the environment at all stages of its life cycle, from the extraction of raw materials, energy sources during operation, to the final disposal of its components. Thus, materials, methods, technologies, and main construction system of the Casa FENIX 2.0 are aligned with this objective. Casa FENIX 2.0 addresses innovation through flexibility and adaptability of the architectural space and systems. However, it is the implementation of Timber Joinery Robotic (CAR), flexible systems, and sustainable energy strategies that will make this proposal possible.

In terms of energy consumption, Casa FENIZ 2.0 will be a Zero-Energy social housing to lower power bill for low-income neighborhoods. This will be addressed by using a grid-connected solar PV system, allocated on the roof of buildings, with a capacity of 297MWp and with an annual generation of 432MWh. For each unit of the Casa FENIX neighborhood, we estimate an average of 1.9 MWh per year for power consumption in electrical appliances, inverters, and lighting. Meanwhile, the estimated energy production for each unit by means of PV, is 4.48 MWh per year. Therefore, 2.58MWh of electricity is available for radiant electrical heating systems and DHW per year. Also, the availability of energy storage will be an important feature in case of earthquake blackout. For this, we will provide a Powerwall with Lion-Fe batteries.

This system will have 8 solar modules Yingly Solar YL250P-29b_IEC_2012-01 and 1 Inverter SMA Sunny Boy 2000 HFUS (USA/120V/60Hz). The HVAC heating system is provided by a thin film electric radiant layer under floors and digitally controlled. For air ventilation a heat recovery vents with 80% efficiency alternate on the mild seasons with natural ventilation. Lighting will be using high efficiency LED luminaries BMS controlled. All the home appliances are rated A++ including a heat pump water boiler for Domestic Hot Water (DHW). Water efficiency is mandatory in such a dry environment. Therefore, water saving appliances such as taps, showers and toilets are included. Also recycling of the greywater system to irrigate the garden in common spaces. Gardens will be planted with native varieties, which water demand is less and they are better adapted to the climate.

Robotic Manufacturing: The key for Flexible Timber Architecture.

The Casa FENIX 2.0 dwelling develops a novel transformable building system, which is not only fully made of timber structure and skins, but also innovates on mid-height timber structures for housing in Chile from its manufacturing approach. The proposal uses engineered wood and a structural approach based on robotic carpentry and complex-geometry joints. The 5x5m wooden grid is industrially manufactured through robotic parametric design (Timber Joinery Robotics) composed of linear components of glulam timber with robotically carved out joints. We use the high-precision and high-replicable approaches of robotic manufacturing to enhance the opportunities of wooden structures in modern architecture and fast construction due to the demands of family homes in the face of a fire catastrophe.

Timber Joinery Robotics (CAR) is a CAD/CAM and engineering wood construction technique, using industrial robotic manufacturing and manual assembly for a timber-framed house. This technique offers a value proposition based on the prefabrication of wood framing with woodworking joints (joinery) of complex geometry, capable of being assembled, disassembled, and reconfigured over time according to different needs and opportunities of occupants. It is based on the methods and philosophy of Mass Customization and Flexible Manufacturing Systems.

Market competitiveness together with product flexibility, which is a pillar of our proposal, can be achieved through the use of CAR relates to the ability to provide customized products or services through flexible robotic processes in low-to-mid volumes and at reasonably low costs. One of the fundamental approaches to consolidate manufacturing for MC is through Flexible Manufacturing Systems (FMS). FMS consist of computer numerically controlled (CNC) machines and other programmable automation and can produce a variety of products on the same system. In our case, the robotic manufacturing approach developed at the School of Architecture UTFSM is a great example of a FMS. Because they do not use dedicated tooling, FMS systems are economical when the production volumes are low, and a large variety of parts are produced. The CAR construction method and system uses wood as a building material, as it is a renewable natural resource, which also allows the reuse and recycling of the construction elements manufactured with this technique.

As part of the flexible manufacturing approach described above, we have proposed a main CAR timber structural system composed by post and beam framing that allows for continuous on-demand metamorphosis of spaces based on inhabitants' need for changes. The design contemplates a new system of interior walls that can move and set according to the needs of each family during the lifetime of the house. These walls will be able to incorporate systems, such as water or electrical, taking the adaptability of the house to its maximum level.

The secondary structure of the housing units of each building is composed of wooden lattices assembled by boxes and spikes of complex geometry, machined by CAR methods. Walls and floors are built of removable members and allow transforming the dwellings post occupation. The structural and spatial components created by means of CAR are locked to form a durable structural continuous system. However, they can be individually dismantled for maintenance, repairing, replacing, or transforming, without damaging its structure. This flexible feature fostered by CAR is unprecedented in the history of Chilean social housing.

Figure 01:Lifting of the main structure; source: Team Chile

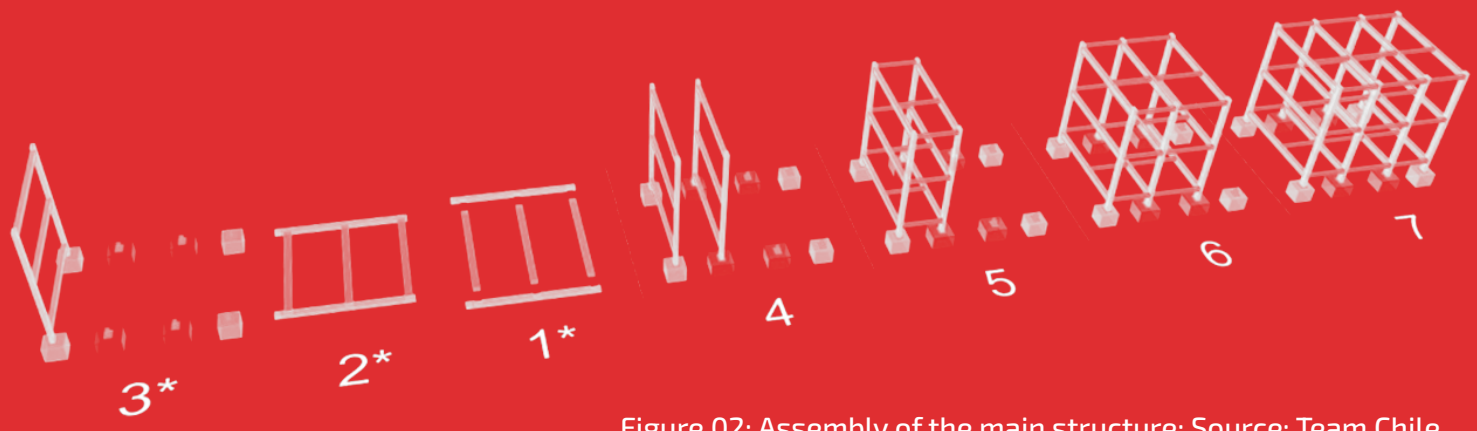


Figure 02: Assembly of the main structure; Source: Team Chile

WOOD FIELD IN CHILE

Chile has a consolidated timber industry. Last year Chile exported USD$6.836 million and produced 16.3 million tons of wood products. Therefore, timber has great potential to be the main construction material for buildings. Chile is also a major contributor in the global forestry market and scene. For instance, the World Conference on Wood Engineering 2020 will be held in Chile. In addition, the Ministry of Housing has committed to double the wood-based social housing by the year 2025, and is supporting the construction of the first mid-height social housing wood building (six stories high) in the city of Rancagua (VI region of Chile).

Sustainability of wooden construction. For the general public, sustainability of wood as construction material is undeniable. However, currently, the Chilean housing industry still uses reinforced concrete as the main construction material; even considering that reinforced concrete construction is time consuming, demands high energy, produces high CO2 emissions and uses large amounts of water. Nonetheless, reinforced concrete has been largely validated as an efficient technology in terms of earthquake resiliency and behavior.

Innovating with wooden construction. Low-height timber-based construction is relatively new in Chile. However, we have the opportunity to demonstrate that there is a substantial market for it based on its benefits regarding rapid construction, industrialized production, low price, and a commitment for sustainability.

Removable assembly joints post occupation. The cost of mechanical joints among wooden components in new construction is generally very high. If materials and labor are considered, these kinds of costs can get up to 20-25% of total structure costs. In comparison, carpentry joints are cheaper due to a reduction of metallic components and behavior against fire that are associated with that task. However, sometimes timber joinery requires highly specialized labor.

Unfortunately, fine carpentry and associated knowledge we used to see in the early 20th century have almost completely disappeared. This lack of base-knowledge and associated labor has affected the quality and cost of timber construction in Chile and the developing world. In contrast, more-developed countries, besides their deeper commitment with wooden construction traditions, have implemented automation at higher rates than countries like Chile, which have resulted in more mature timber-construction industries and related lower production costs.

Some preliminary studies have identified a low offer of high-precision wood manufacturing capabilities in Chile. As mentioned before, qualified carpentry labor has become harder and harder to find with a subsequent raise in the cost of such a kind of labor. In addition, although there is some installed infrastructure for high-volume production of wooden standard components and materials, custom building components such as prefab walls or windows do not take advantage of high-volume cost reductions.

Currently, in Chile there are around 500 industrial robots installed. These units are commonly found in the mining industry, food industry, and metalworking industry. Yet, in the construction industry this kind of technology is seldom seen. In contrast, mass-produced affordable wooden housing, advanced manufacturing wooden components, and engineering wood products lead the agenda of sustainable construction of the country. In order to meet these expectations, the CAR manufacturing system proposed by Team Chile appears as a great opportunity to reduce the gap between traditional timber-construction knowledge and technological industry advancements by means of providing affordable and sustainable methods to develop social housing.

Figure 03 :The Chilean company MIRS partnered with a world leading manufacturer in the field of robotics, the German KUKA RoboterGmbH, with the intention of developing custom robotic applications for mining and heavy industry.; Source: Trendtic.cl

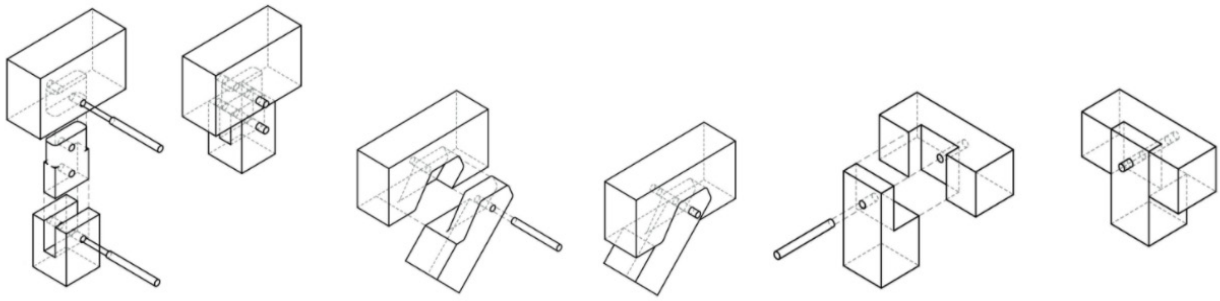
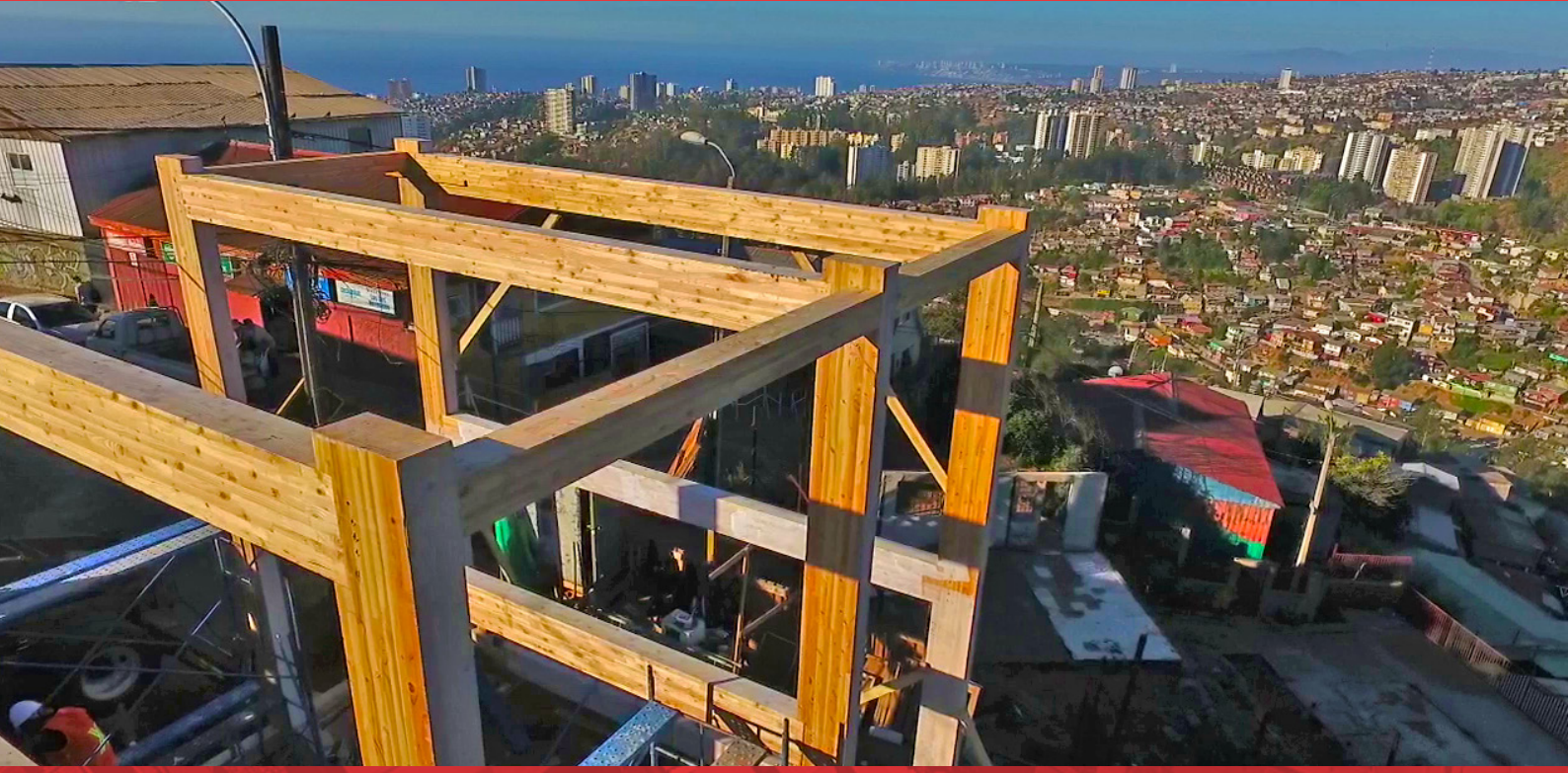


Figure 04: Detachable joints after occupation; Source: Guentelicán, 2019.



As expected, it was possible to determine that the most favorable construction typology for the space transformation is the post and beam construction system. When considering symmetrical and orthogonal proportions the system does not require greater reinforcement of diagonals, leaving only the enveloped/partition diaphragms as secondary structure. On the other hand, as it is a structured system designed to be prefabricated and modular, production costs and construction times decrease in theory and provided the industry is technically and machinery prepared for it. This constitutes one of the key factors for market potential.

The Robot Assisted Carpentry (CAR) has several advantages, among them three can be technically defined: The first corresponds to the specific joint for used in the proposed construction system, which by being elastic or not completely rigid, contribute to the global structure of the building, providing greater resistance to damage caused by earthquakes. The second, proposing an orthogonal structural system allows greater flexibility to the design diaphragms, allowing a faster and more efficient development in terms of modular height increase and as elements for CAR's joints. The last, when using exclusively CAR's joints, it was found in the literature that it provides the proposed structure type with greater resistance to fire, increasing its collapse time, carbonizing the wooden elements before reaching the core for the subsequent collapse. This is a very important factor for families that had lost homes in an urban fire, which will be the case for the family that Casa FENIX 2.0 prototype is for.

Wood structural systems by themselves are largely sustainable, since they absorb CO2 throughout their life cycle. In addition, if we consider that it is a system designed to be prefabricated and modular, the decrease in the carbon footprint will be even greater through the buildings life cycle, reducing emissions with less use of machinery, less pollution when prefabricating and less pollution during construction. Wood emits 10.9% of the total CO2 emissions of steel and 17.8% of the total CO2 emissions of a concrete throughout its life cycle, considering the emission of the structure from its extraction to its construction.

Finally, in addition to everything previously described, the use of sustainable and nationally manufactured wood for building construction, with a good forest management from the beginning, besides from contributing to the benefits of CO2 emissions from its raw material, enhance the sustainability of the project even more by extending longer its life cycle, being this a great opportunity for a emerging and necessary new market. Team FENIX has the big task to pursue a sustainable and social economical evaluation of these market potential features.

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